Abridgment

Pavement Width Standards for Rural Two-Lane Highways

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For a number of years, Idaho's pavement policy has included full-width pavement with shoulders paved the same thickness as the roadway. Overall widths have conformed generally to AASHTO standards. These standards were accepted in the absence of a formal analysis of local conditions suitable for establishing width criteria.

This study was undertaken to analyze local data and to obtain relationships among pavement width, construction and maintenance costs, and accident costs for rural two-lane highways. The investigation included two major phases: first, a statistical analysis of accident records to investigate the effects of width and other factors and, second, using accident trends determined from the first part of the study, economic analyses to evaluate the overall economic effects of different pavement widths in various average daily traffic ranges.

ACCIDENT ANALYSIS

Accident records from 1972, 1973, and 1974 were analyzed. Urban sections, unpaved roads, sections with more than two lanes, and sections with average daily traffic (ADT) greater than 3000 vehicles were excluded. A total of 664 highway sections in Idaho and 332 sections in Washington were studied. Very few of the sections had edgeline paint stripes during the study period. Section length varied between 1.6 and 16 km (1 and 10 miles). Study sections were further classified according to ADT and terrain type, using six levels of ADT and, initially, three levels of terrain. Accident rates in terms of accidents per 1.6 million vehicle-km (1 million vehicle-miles) were separated into three categories: property damage only, personal injuries or fatalities, and total accidents.

Statistical analysis of the accident data followed a procedure somewhat similar to an earlier Oregon study (1). Two steps were involved. First, product-moment correlations and partial correlations were employed to measure the extent of the linear relationship between accident rates and pavement widths. In the second step, variance and covariance procedures were used to determine whether there were statistically significant differences among accident rates in the different width classes.

The Pearson product-moment correlation technique was used to measure the extent of linear correlation between accident rate and terrain type, pavement width, section length, and ADT in each of six ADT ranges. Terrain and pavement width were found to be considerably more significant in a statistical sense than were section length and within-group ADT variation.

Table 1 shows the correlation coefficients in the various ADT ranges, considering total accident rates only. The positive signs on the significant terrain coefficients indicate increasing accident rate as the terrain becomes more severe. The negative signs on the width coefficients indicate decreasing accident rate as width increases. The effects of section length and within-group ADT are generally less significant than terrain and pavement width. This analysis only indi-

Table 1. Product-moment correlations.

ADT Range	Terrain	Width	Length	ADT	No. of Cases
0-249.99	-0.0203	-0.1457	0.1399	-0.0038	52
250-399.99	0.4022[a]	-0.2819[a]	-0.2027	0.0873	78
400-749.99	0.1833[a]	-0.1335[a]	-0.0423	-0.1418[a]	205
750-999.99	0.4526[a]	-0.2855[a]	-0.3545[a]	0.1014	123
1000-1999.99	0.1035	-0.3942[a]	-0.0417	-0.1657[a]	338
2000-2999.99	-0.0851	-0.3855[a]	-0.2167[a]	-0.0054	200

[a]Significant at the 0.05 level.

Table 2. Partial correlations.

ADT Range	Terrain	Width	Length	ADT	No. of Cases
0-249.99	-0.007 56	-0.103 85	0.098 87	0.023 74	52
250-399.99	0.395 85[a]	-0.288 40[a]	-0.155 72	0.140 21	78
400-749.99	0.148 03[a]	-0.127 35	-0.081 91	-0.087 61	205
750-999.99	0.417 01[a]	-0.200 09[a]	-0.354 14[a]	-0.076 62	123
1000-1999.99	0.086 65	-0.395 25[a]	-0.108 73[a]	-0.143 09[a]	338
2000-2999.99	0.074 76	-0.408 38[a]	-0.265 34[a]	-0.000 40	200

[a]Significant at the 0.05 level.

Table 3. Analysis of variance.

Source of Variation	Mean Accident Rate	Sum of Squares	Degrees of Freedom	Mean Square Error	F
Paved width (m)					
4.9-6.7	3.10				
7.9-14.0	2.16				
		158.398	1	158.398	75.78[a]
ADT range					
0-249.99	2.9531				
250-399.99	2.5204				
400-749.99	2.3409				
750-999.99	2.8909				
1000-1999.99	2.6116				
2000-2999.99	2.2497				
		68.379	5	13.67	6.54[a]
Interaction		16.551	5	3.31	1.58
Residual (error)		1584.508	756	2.09	
Total		1827.836	767		

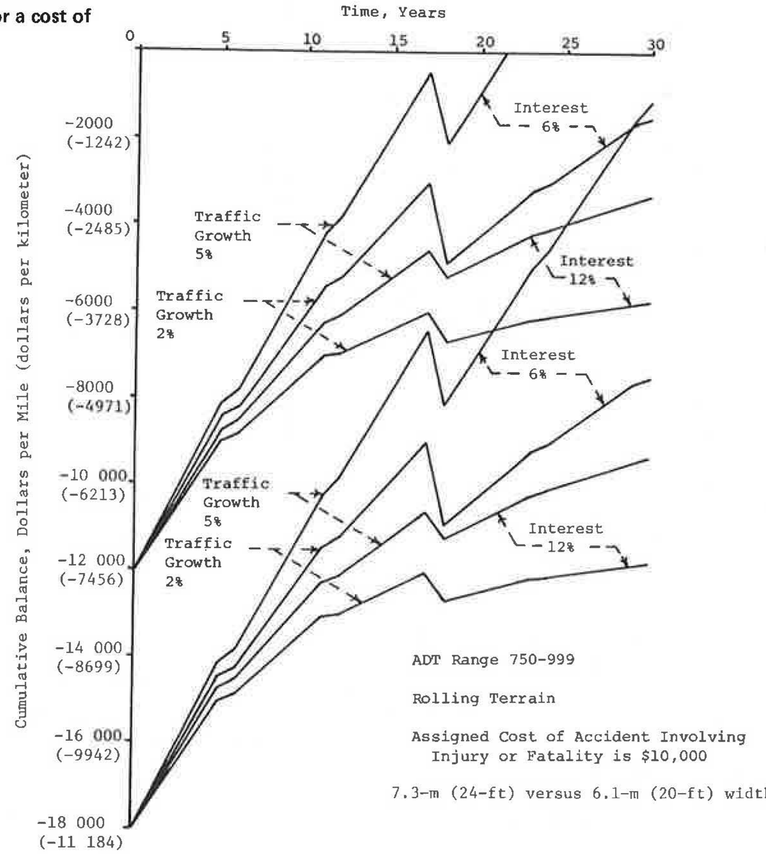
Note: 1 m = 3.3 ft.
[a]Significant at any reasonable confidence level.

Table 4. Analysis of covariance.

Source of Variation	Mean Accident Rate	Sum of Squares (adjusted)	Degrees of Freedom	Mean Square Error	F
Paved width (m)					
4.9-6.7	3.099				
6.7-7.9	2.738				
7.9-14.0	2.159				
		143.763	2	71.881	29.821[a]
Error		2386.307	990	2.410	
Total		2530.070	992		

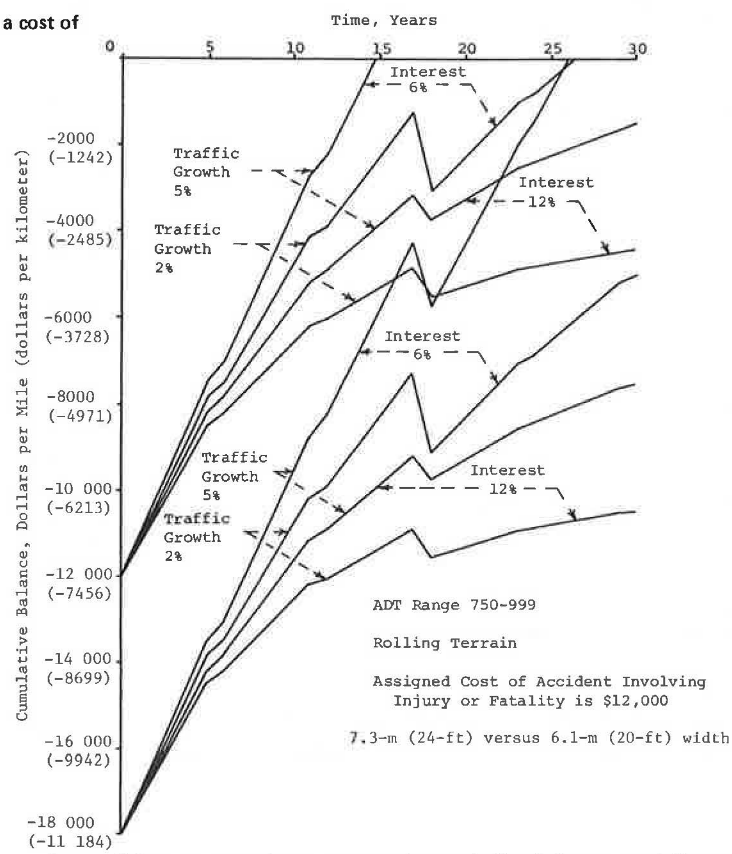
Note: 1 m = 3.3 ft.
[a]Significant at any reasonable confidence level.

Figure 1. Present-worth investment return analysis for a cost of $10 000 per accident.



Notes: Values in parentheses are cumulative dollar balances per kilometer. This example uses Idaho data only.

Figure 2. Present-worth investment return analysis for a cost of $12 000 per accident.



Notes: Values in parentheses are cumulative dollar balances per kilometer This example uses Idaho data only.

cates that the linear relationship is significantly different from zero but does not necessarily imply direct cause and effect between variables.

Partial correlation was next attempted, partly because the trends revealed by the product-moment correlation had to be verified and partly because partial correlation has the additional feature of determining whether a causal relationship exists. Table 2 summarizes the partial correlations.

The preceding tables indicate that a basic linear pavement-width and accident-rate relationship can be inferred with high confidence in some ADT ranges but not in others, based on the data used in this study. A second observation is that the significant terrain coefficients are often numerically larger than the corresponding width coefficients, indicating that terrain constraint sometimes has a stronger linear relationship with accident rate than does pavement width.

Next a factorial analysis of variance was performed. The factorial design allows study of interactions among the variables involved. Only pavement width and ADT range were investigated in this portion of the study. Section length was not considered, because the preceding analysis showed its effect to be small. Terrain type was eliminated partly because it was not the variable of primary interest and partly because of small sample sizes in some terrain categories in certain ADT ranges. Table 3 lists mean total accident rates for two width ranges and six ADT ranges. Statistical variance testing indicated with a high degree of confidence that the observed differences in accident rates were significant.

The final type of statistical analysis performed was analysis of covariance, which has the advantage of controlling secondary factors so the true effect of the primary factor can be determined. Table 4 shows the mean accident rates for three levels of pavement width. The covariance analysis controlled all other effects so only pavement width and an error factor remained as sources of variation. The analysis indicated with a high degree of confidence that variations in accident rates resulted from the differences in pavement width.

ECONOMIC ANALYSIS

The accident study revealed a tendency for accident rates to decrease with increased pavement width, but of course highway cost increases with increased pavement width. It is desirable to evaluate the cost of wider pavement in comparison with potential cost savings resulting from accident reductions associated with wider pavement. For this purpose we chose a present-worth evaluation similar to that used in a North Carolina study (2). Interest rates of 6 and 12 percent were used to cover a range of representative values.

Construction costs were estimated using 1975 Idaho Division of Highways contractor bid prices. Construction cost increases for a 1.2-m (4-ft) wide strip of additional fill material, base, and paving were estimated to be $7085/km ($12 000/mile) on flat ground and $11 184/km ($18 000/mile) in more difficult terrain. Proportionate costs were calculated for other width changes.

Major maintenance operations were assumed to be chip seal coats at 6-year intervals and a 9.1-m (0.3-ft) thick overlay at 18 years. Estimated costs were $373/km ($600/mile) for seal coating and $3728/km ($6 000/mile) for the overlay on a 1.2-m (4-ft) wide strip.

Routine maintenance cost differences were estimated using data supplied by the Nevada Department of Highways. Computerized records covering 1 year and 4 months during 1973-1974 indicated routine maintenance costs for 3701/km (2300/miles) of 7.3-m (24-ft) pavement were about $31.06/km ($50.00/mile) lower than for 2253/km (1400/miles) of 6.1-m (20-ft) pavement. This relatively small difference was found to have no significant effect on the overall economic analysis.

Economic values associated with individual accidents were initially assumed to be $500 for an accident involving property damage only and $10 000 for an accident involving injury or loss of life. The effect of assuming values up to $20 000 as the average cost of an injury or fatality accident was also investigated. Average accident costs per kilometer were computed separately for six ranges of ADT and six nominal pavement widths. Initially, separate computations were made for each terrain type, but all terrain types were later merged to increase the number of roadway sections in each study category. Furthermore, eliminating terrain type facilitated comparisons with existing Idaho Division of Highways width standards, because minimum pavement widths are now the same for all terrain types. Only minimum standards for speed, foreslope steepness, curvature, grade, and stopping sight distance are changed to reflect terrain type.

For each study category, a weighted average accident

Table 5. Number of years required to pay back costs of wider pavement based on accident cost savings.

Initial Cost Difference ($/km)	Annual Interest (%)	Annual Traffic Growth (%)	No. of Years to Pay Back Costs by Construction-Year ADT: 0-249	250-399	400-749	750-999	1000-1999	2000-2999
11 184	6	2	–[a]	–[a]	–[a]	–[b]	13	9
		5	–[a]	–[a]	–[a]	26	11	8
	12	2	–[a]	–[a]	–[a]	–[b]	–[b]	14
		5	–[a]	–[a]	–[a]	–[b]	16	11
16 776	6	2	–[a]	–[a]	–[a]	–[b]	25	15
		5	–[a]	–[a]	–[a]	–[b]	16	12
	12	2	–[a]	–[a]	–[a]	–[b]	–[b]	–[b]
		5	–[a]	–[a]	–[a]	–[b]	–[b]	23

Note: 1 km = 0.62 mile.

[a]The wider [10.4-m (34-ft)] pavement had a higher accident rate than the narrower [8.5-m (28-ft)] pavement.

[b]The narrower pavement had the higher accident rate but the costs were not paid back for 30 years.

Table 6. Comparison between existing Idaho minimum pavement widths and suggested minimums.

Range of Current ADT	Average 20-Year ADT of Sample Sections in the Given Range of Current ADT (2% growth)	DHV (assume 13% of 20-year ADT)	Suggested Minimum Width (m)	Idaho Minimum Width for Primary Highways (m)	Idaho Minimum Width for Secondary Highways (m)
0-249	246		6.1	7.9-8.5	7.9-8.5
250-399	467		6.1	10.4	8.5
400-749	851	111	7.3	10.4	10.4
750-999	1294	168	8.5	10.4	10.4
1000-1999	2124	276	10.4	12.2	12.2
2000-2999	3643	474[a]	12.1	13.4	13.4

Note: 1 m = 3.3 ft.

[a]Idaho design standard calls for four-lane design when DHV exceeds 400.

rate was computed for a 1.6-km (1-mile) section, using the accident records for that category. Future ADT was estimated for each of the next 30 years, using both 2 and 5 percent annual traffic growth. The 30-year period was estimated to be a reasonable interval during which no major reconstruction would likely be required. For each of the 30 years, a cumulative summation of costs and benefits was made under each combination of assumptions about traffic growth, interest rate, and initial cost difference. Accident rate was assumed constant over the 30 years.

Figures 1 and 2 illustrate the general features of the analysis. Traffic growth is 2 percent annually for both figures. The point at which the curve crosses the horizontal axis is the year in which the savings due to accident reductions would repay the added cost associated with the wider paved road. Comparison between the two figures illustrates that the analysis is somewhat sensitive to changes in the economic value assigned to each injury or fatality accident. A condensed form of data presentation was used in evaluating the results of the computations. This is illustrated in Table 5 for one set of conditions.

CONCLUSIONS

Using the foregoing type of analysis, a table of suggested minimum paved widths was prepared. Table 6 compares the suggested minimums with existing Idaho Division of Highways standards. Because the analysis is relatively sensitive to injury or fatality accident cost, the suggested minimums should be reevaluated if the average cost of such accidents increases significantly, or if accident trends change significantly.

ACKNOWLEDGMENTS

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Earth Berms and Their Actual and Perceived Effects on Noise and Privacy in Adjacent Neighborhoods

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The purpose of this paper is to compare and assess the measured and calculated attenuations obtained from earthen sound berms and also to assess the perceived effects of selected berms on adjacent residential neighborhoods by means of an attitudinal survey. Simultaneous sound readings were taken before and after construction of the berms. It was found that they produced median sound-level attenuations of 5 dB(A) at the right-of-way line and 3 dB(A) at a distance corresponding to the front sidewalk of the homes along the freeway. The attitudinal survey, conducted before and after the construction of sound berms, indicated that residents immediately adjacent to the freeway perceived a reduction in sound levels and increased privacy both indoors and outdoors. The study concluded that even minor attenuations of freeway noise of 5 dB(A) or less are discernible within adjacent neighborhoods and, based on the subjective responses of the attitudinal survey, are perceived to be greater than actually measured. Also, the increased privacy afforded by sound berms should be a consideration in the evaluation of proposals for the construction of future sound-attenuating devices.

In the fall of 1971 the Milwaukee metropolitan district office of the Wisconsin Division of Highways undertook a series of safety improvement projects, particularly concrete median barriers, on the interstate freeways within its jurisdiction. During the design of these barriers it became evident that there would be an excessive amount of earth material that would have to be removed from the project sites. It was decided that, rather than waste this material on private dumping areas, it could be used to develop experimental acoustical barriers at selected sites along the freeway that were near the sites. It was felt that the barriers would serve two purposes: They could be used as sound deflectors to reduce freeway noise levels for land uses along the freeway and they could function as privacy shields between the freeway and the adjacent land developments.

Because the use of such berms was experimental, it was felt that a study should be done to obtain first-hand information on the benefits and design of these barriers. Consequently, a before-and-after study was undertaken to determine the effectiveness of the earth berms in sound attenuation and to serve as a guide for future design and construction of these devices.

The initial intent of the before-and-after study was a series of sound-level readings to measure the actual attenuation realized from the barriers. However, a literature search revealed a number of studies that had already measured attenuation of barriers of this nature (1, 2, 3, 4). All of these studies, nevertheless, indicated